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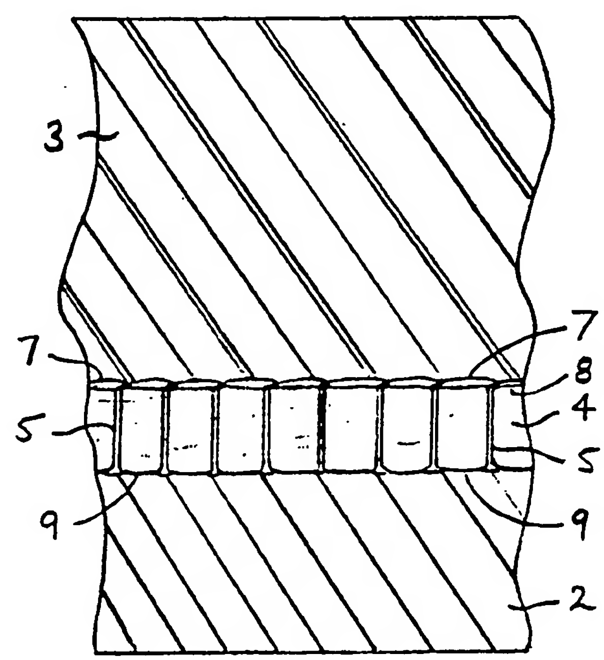
(54) Composite lining material

(57) A composite lining material has a thermoplastics sheet (2) (e.g. of polypropylene) bonded to one face of a non-woven web (4) of fibres (e.g. polyester) through which continuous filaments (5) (e.g. of polyester) are stitched, for example in chain or tricot stitch. A reinforcing layer (3), for example of fibre-reinforced resin, is applied to the other face (8) of the web (4) to provide a lined wall structure which may be the wall of a lined pipe, vessel or tank.

The continuous filaments (5) are bonded to the lining and reinforcement layers (2, 3) at multiple, spaced locations (9) and provide a direct, mechanical link between those layers in addition to reinforcing the fibrous web (4). Shear strengths of greater than 100 kg/cm² and steady peel strengths of greater than 7.0 kg/cm properties at elevated temperatures.

Fig. 4



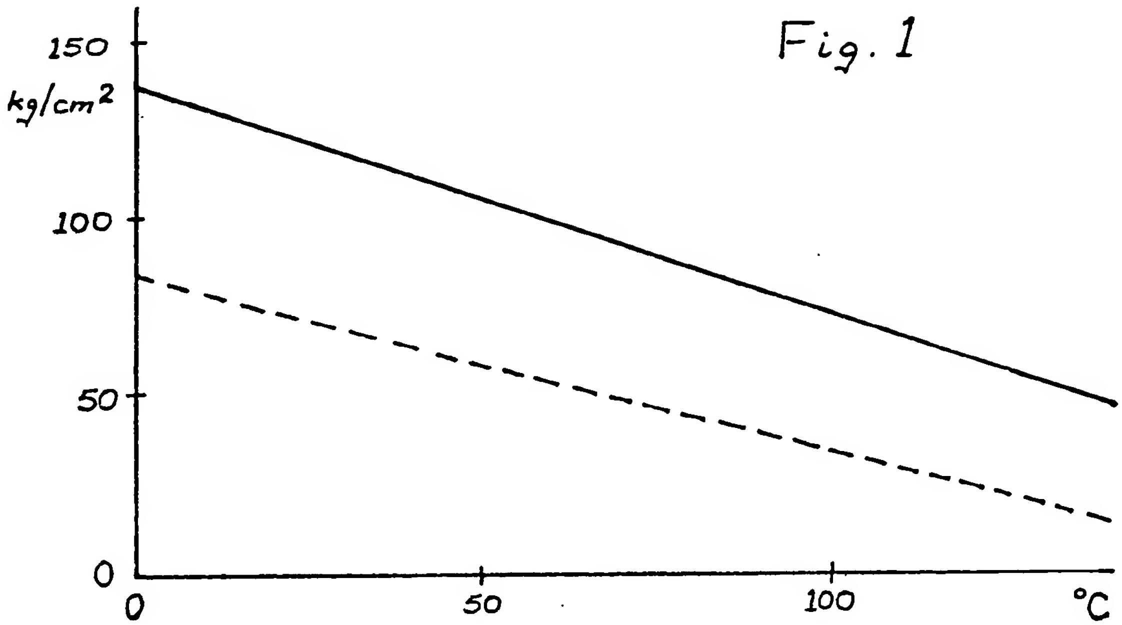


Fig. 1

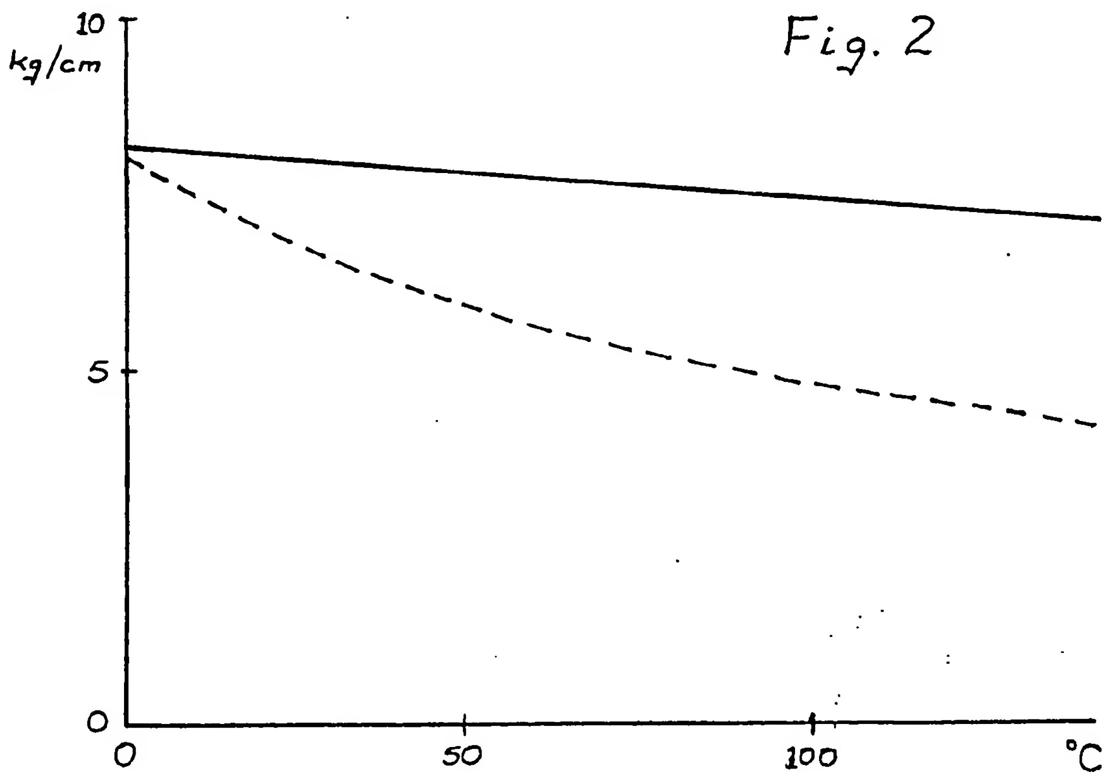


Fig. 2

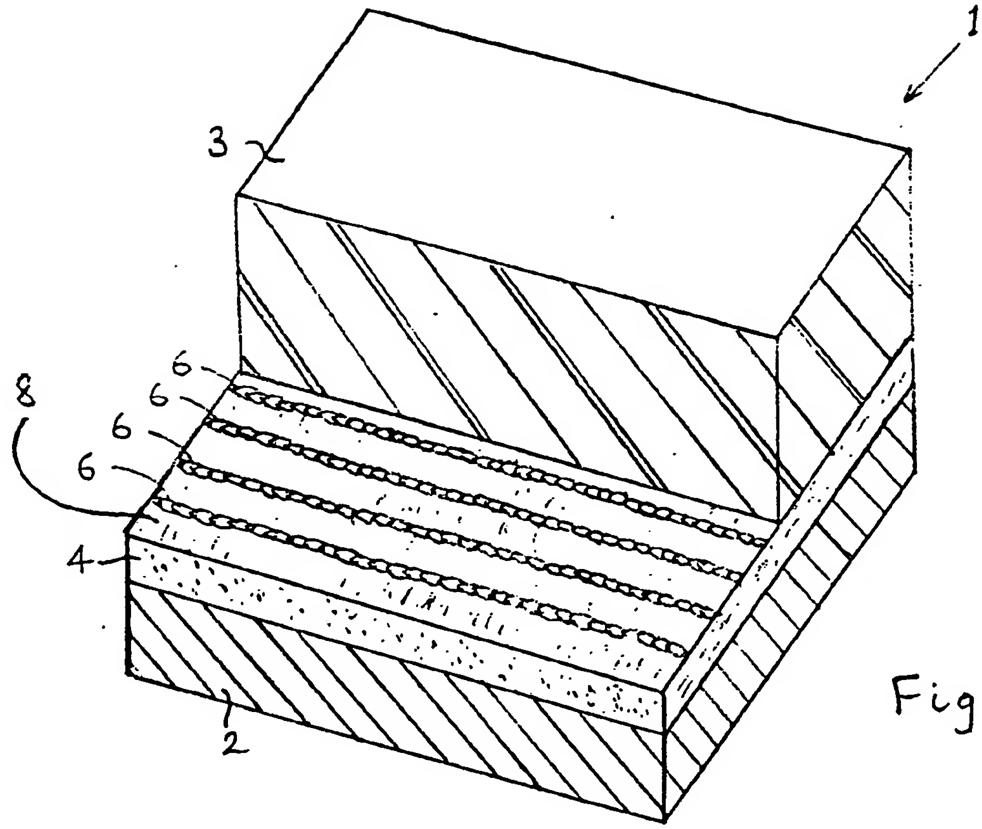


Fig. 3

Fig. 4

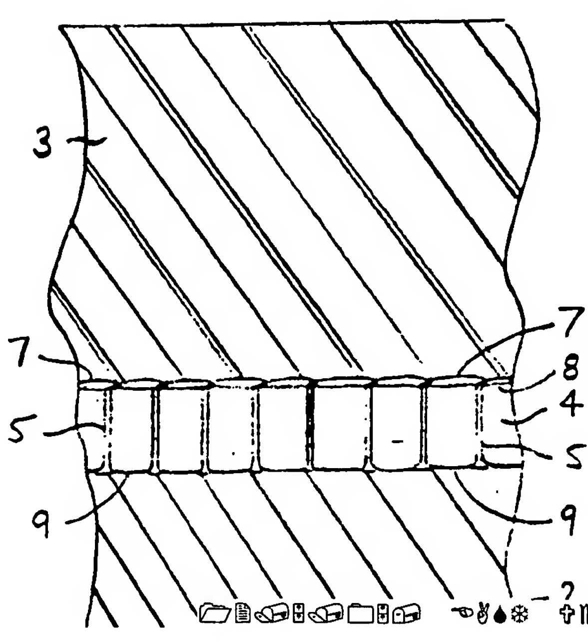
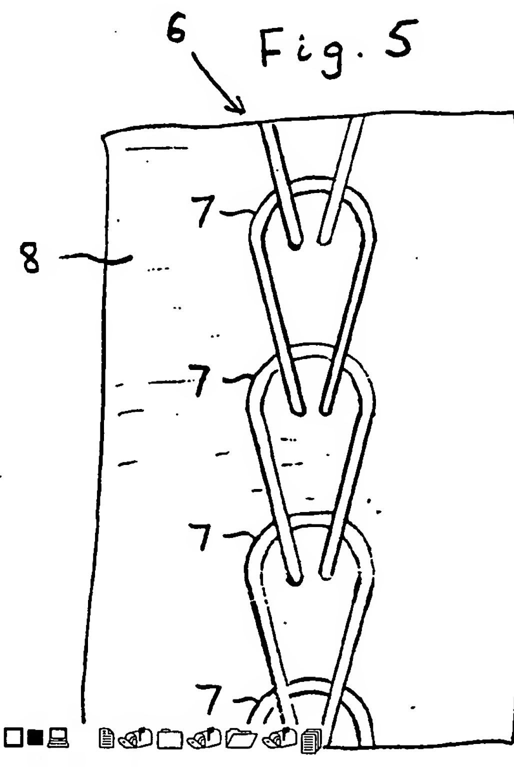


Fig. 5



SPECIFICATION
Composite lining material

This invention relates to a composite lining material suitable for bonding to a reinforcement material.

U.S. Patent Specification No. 3,489,639 describes such a lining material which comprises a thermoplastics sheet bonded to a woven, knitted or non-woven fabric comprising both glass fibres and thermoplastic fibres. The thermoplastic fibres provide good adhesion to the thermoplastics sheet, and the fabric as a whole is a receptive layer to which a bulk reinforcement material such as fibre-reinforced resin will bond. U.S. Patent No. 4,228,208 describes the same type of lining material in which the fabric has a pile for improved bonding with the reinforcement material.

One of the primary uses for such composite lining materials is in the construction of chemical plant to provide a chemically-resistant lining for vessels, tanks and pipes. Clearly in such end uses, good adhesion between the lining material and its reinforcement is essential to the performance of the structure. The term 'lining' is not meant to be confined to internal surfaces only but is meant to include outer surfaces such as facings and claddings.

According to this invention a composite material suitable for bonding to a reinforcement material comprises a lining layer of a thermoplastic material having a lining face and a reverse face, a non-woven fibrous web having one of its faces bonded to the reverse face of the lining layer and its other face exposed, and continuous filaments which are stitched through the web and which pass back and forth between the exposed face of the web and the reverse face of the lining layer, the continuous filaments being bonded to said reverse face of the lining layer at multiple, spaced locations.

As acknowledged earlier, non-woven fabrics have been proposed previously for this purpose because they are inexpensive compared with woven fabrics. Those used commercially have comprised needle-punched webs which give reasonable performance in many end uses but are not so suitable where higher performance is required. An examination of the mode of failure of structures comprising a reinforced composite lining material made with such fabrics has shown that failure tends to take place within the fabric structure itself rather than by delamination of the fabric from the lining layer or the reinforcement layer.

The fabric used in the composite lining material of the invention overcomes this disadvantage because the fibrous web is itself reinforced by the continuous filaments stitched through it, and furthermore these filaments, being bonded at multiple, spaced locations to the lining layer and also available to a reinforcement material on the exposed face of the web, provide a strong direct link between the lining layer and the reinforcement material.

The lining layer may be any thermoplastic material which can be formed into sheet or other shapes, such as moulded or extruded pipes or vessels, and which is suitable for the lining duty required. For chemical plant, chemically-resistant thermoplastics are preferred, particularly polypropylene and poly(vinylidene fluoride). Other suitable thermoplastics include other polyolefins, polycarbonates, polyethers, polyaldehydes, polyvinyls and polystyrene.

The non-woven fibrous web may be a staple fibre web formed by conventional carding and laying techniques. The term 'web' is meant to embrance multilayer web assemblies such as fleeces. Continuous filament webs may also be used such as those formed by spreading a tow of filaments by suspending the tow in diverging air currents or in a diverging flow of liquid and then dry or wet laying the spread tow to form a coherent web of filaments.

The fibres of the web are preferably synthetic fibres. Polyester fibres are especially suitable because of their chemical resistance. The continuous filaments used to stitch through the web are required to have adequate strength for their purpose of reinforcement and the synthetic filaments are suitable in this respect, with polyester filaments being preferred because of their combination of strength and chemical resistance. Another advantage of polyester filaments is that they do not soften at the laminating temperatures used with the preferred polypropylene lining layer.

The web may be stitched on any suitable stitching machine, particularly the high output machines sold under the "Mali" and "Arachne" names. The stitch construction may be a simple chain stitch or a tricot stitch or a combination of the two. The stitching guage and the stitching rate may be selected to give the desired degree of stitch reinforcement.

The stitched web may be bonded to the thermoplastic lining layer using an intermediate adhesive material, but the preferred method is to soften the reverse surface of the lining layer using heat or solvent action and then to fuse the face of the stitched web to the softened surface. The exposed parts of the continuous filaments stiched through the web also fuse to the softened surface of the lining layer at multiple locations. With a lining layer comprising a sheet, the stitched web may be calendered to the sheet whilst its surface is still soft immediately after extrusion as described in the aforementioned U.S. Patent No. 3,489,639.

The invention includes a wall structure comprising a lining layer of a thermoplastic material having a lining face and a reverse face, a layer of reinforcement material, a non-woven fibrous web having one of its faces bonded to the reverse face of the lining layer and the other of its faces bonded to the layer of reinforcement material, and continuous filaments which are stitched through the web and which pass

back and forth between the lining layer and the reinforcement layer, being bonded to each of said layers at multiple, spaced locations.

The reinforcement material may be a synthetic resin reinforced with fibres such as G.R.P. (glass reinforced polyester resin). It may be applied to the exposed face of the stitched web by any of the usual techniques including hand lay-up, spraying, moulding and casting. Resins do not simply bond to the face of the stitched web but are absorbed by it and thereby envelop both the web fibres and the stitching filaments to provide a strong mechanical bond.

A certain amount of resin usually is applied to the stitched web to wet it out prior to application of the G.R.P., and it has been found that for this purpose less resin per unit area is required with the stitched web than with a needle-punched fabric of similar basis weight. In addition to the saving in resin, there is a valuable saving in fabrication time.

The wall structure of the invention may comprise the wall of a pipe, vessel or tank for which the lining layer provides an internal lining. It may also be the wall of a building having an external or internal lining.

The wall structure of the invention has improved properties in shear and in peel as measured by the tests described in the following Examples. Measured at 20°C., shear forces of greater than 100 kg/cm^2 and steady peel forces of greater than 7.0 kg/cm are obtainable. Moreover, these properties do not fall off drastically at elevated temperatures. At 50°C., shear forces greater than 100 kg/cm^2 are maintained, and at 100°C., the value of shear force is still in excess of 50 kg/cm^2. In steady peel, the maintenance of properties is even more impressive because, over the temperature range of 0°C. to 100°C., the rate at which steady peel force falls is less than 0.01 kg/cm per 1°C. rise in temperature.

The invention is illustrated by the accompanying drawings in which:

Figure 1 comprises a graph plotting values of shear force for wall structures according to the invention against temperature;

Figure 2 comprises a graph plotting values of steady peel force for wall structures according to the invention against temperature;

Figure 3 is a schematic perspective, partly cut away, of a wall structure according to the invention;

Figure 4 is a cross-section through a wall structure according to the invention adjacent to a line of chain stitch in the fibrous web; and

Figure 5 is a enlarged plan view of a series of interconnected stitch loops forming part of such a line of chain stitch.

Figures 1 and 2 of the drawing are referred to in Example 2. Figures 3 and 4 show a wall structure 1 which is according to the invention and which comprises a lining layer 2 of a thermoplastic material, a layer 3 of a reinforcement material, and bonded between those layers, a non-woven fibrous web 4 reinforced by continuous filaments 5 stitched through it in lines of chain stitch 6.

Figure 5 shows an enlarged view of a series of interconnected stitch loops 7 forming part of such a line of chain stitch 6. These loops lie against that face 8 of the fibrous web which remains exposed after the web has been fused to the lining layer 2, and to which the reinforcing layer 3 is subsequently bonded.

As shown in Figure 4, the continuous filaments 5 which are stitched through the web 4 provide a direct mechanical link between the lining layer 2 to which they are fused at locations 9, and the reinforcement layer 3 which bonds to the stitch loops 7.

The invention is illustrated by the following Examples:—

EXAMPLE 1

Polyester fibres of 4.4 dtex and 100 mm staple length were carded into a web which was then cross-folded to form a fleece. The fleece was stitched using a continuous filament polyester stitching yarn of 78 dtex and comprising 24 filaments on a Maliwatt multiple needle stitching machine. A single needle bar was used, stitching chain stitch at a stitch guage of 8.8 stitches/cm and a stitch rate of 6 stitches/cm. The basis weight of the stitched fleece produced was 165 gms/m^2.

The stitched fleece was bonded to a 2 mm thick sheet of polypropylene extruded at a temperature of 240°C by passing the freshly-extruded sheet and the stitched fleece together through a three roll calender with that face of the fleece on which the chain loops are exposed uppermost and the reverse face against the soft surface of the sheet. The temperatures of the calender surfaces were:—

Top roll	70°C.
Centre roll	90°C.
Bottom roll	85°C.

The sheet and the stitched fleece were passed together between the nip of the top and centre rolls, partially lapped around the centre roll, passed through the nip of the centre and bottom rolls and then partially lapped around the bottom roll.

The composite lining material so formed was reinforced with G.R.P. by applying resin and 'E' glass in the form of chopped strand mat to the exposed surface of the stitched fleece to a depth of 4 mm. The resin was a polyester resin formulation sold by Scott Bader under the trade mark "Crystic" 474 PA. After curing the resin, the bond strength between the composite lining material and the G.R.P. reinforcement was measured in shear and in peel using a Hounsfield tensometer.

The peel test used is one developed by Courtaulds PLC which peels the composite lining material away from the G.R.P. reinforcement at an angle of 90 degrees to the reinforced composite lining material and records the steady value of peel force attained during steady peel following the peak initial value. This test has been found to give more reproduceable results than the peel test specified in British Standard 4994 which measures the value of force to initiate peel.

The values of shear force and peel force were measured at 20°C. and are shown in the following table in comparison with values obtained with prior art composite lining materials. In both cases 2 mm sheets of polypropylene were used and the procedures of lamination, reinforcement and testing were the same as were used with the composite lining material of the invention, but the stitched fleece was replaced by, respectively, a woven fabric and a needle-punched fabric.

The woven fabric was woven in a four shaft satin weave at 10 ends/cm and 10 picks/cm and had a basis weight of 280 gms/m². The warp yarn was of 1,500 dtex and comprised 50 *per cent* by weight of 693 dtex/70 filament polypropylene yarn and 50 *per cent* by weight of 666 dtex glass yarn. The weft yarn was a 100 *per cent* glass yarn of 1,200 dtex. The needle-punched fabric comprised a blend of polyester staple fibres, 50 *per cent* by weight of 3.6 dtex, 58 mm staple length fibres and 50 *per cent* by weight of 5.3 dtex, 50 mm staple length fibres. It was needle-punched at a punch gauge of 100/cm and a punch rate of 2.35/cm and had a basis weight of 160 gms/m².

The quantity of resin required to completely wet-out the exposed face of each of the fabrics bonded to a polypropylene sheet is also shown in the following table.

Composite lining material	Steady Peel force (kg/cm)	Shear force (kg/cm²)	Resin Wet-out (kg/m²)
Woven fabric	4.3	74	0.60
Needle-punched fabric	6.9	81	1.44
Stitched fleece (invention)	7.3	112	0.625

The composite lining material according to the invention using the stitched fleece gives superior peel and shear strengths compared with each of the prior art materials, and requires only the same amount of resin to wet out the stitched fleece as is required by the woven fabric, which is less than half that required by the needle-punched fabric. The stitched fleece was purchased at a price which was about 35 *per cent* of that of the woven fabric and about 70 *per cent* of that of the needle-punched fabric.

EXAMPLE 2

The procedure of Example 1 was repeated except that 3 mm thick polypropylene sheet was used in all cases. Samples of the reinforced composite lining material of the invention and of the prior art reinforced composite lining material which uses a needle-punched fabric were tested in shear and in peel over a range of temperatures. The results are shown in the graphs plotting shear force against temperature and steady peel force (Courtaulds' test) against temperature which comprise Figures 1 and 2 respectively of the accompanying drawing. In each case the results obtained with material according to the invention are shown by a continuous line and those with a prior art needle-punched fabric by a dashed line.

The values of shear force and peel force obtained at 20°C. for all three composite lining materials are shown in the following table:—

Composite lining material	Steady Peel force (kg/cm)	Shear force (kg/cm^2)
Woven fabric	5.0	116
Needle punched fabric	7.0	74
Stitched fleece (invention)	8.0	124

The superiority of the composite lining material of the invention in peel and in shear is shown again with the thicker polypropylene sheet. Moreover, the improved properties are maintained over the temperature range shown. Thus, the value of shear force is about 107 kg/cm^2 at 50°C. and about 75 kg/cm^2 at 100°C. The value of peel force remains above 7.5 kg/cm over the whole temperature range, and falls less than 1 kg/cm as the temperature is raised over that range.

EXAMPLE 3

The procedure of Example 1 was repeated except that 6 mm thick polypropylene sheet was used in all cases. The Courtaulds' peel test was carried out in the same way but the values of peel force quoted in this Example are the initial values because steady peeling was not possible with this thickness of sheet. The comparative performances of the three samples are seen to be maintained with the much thicker 6 mm polypropylene sheet.

Composite lining material	Initial Peel force (kg/cm)	Shear force (kg/cm^2)
Woven fabric	12.6	103.2
Needle-punched fabric	16.6	93.7
Stitched-fleece (invention)	18.3	147.5

CLAIMS

1. A composite lining material suitable for bonding to a reinforcement material comprising a lining layer of a thermoplastic material having a lining face and a reverse face, a non-woven fibrous web having one of its faces bonded to the reverse face of the lining layer and its other face exposed, and continuous filaments which are stitched through the web and which pass back and forth between the exposed face of the web and the reverse face of the lining layer, the continuous filaments being bonded to said reverse face of the lining layer at multiple, spaced locations.

2. A composite lining material as claimed in claim 1 in which the continuous filaments are stiched through the web in the form of chain stitch or tricot stitch or both.

3. A composite lining material as claimed in claim 1 or claim 2 in which the non-woven web comprises synthetic fibres.

4. A composite lining material as claimed in claim 3 in which the non-woven web comprises polyester fibres.

5. A composite lining material as claimed in any of claims 1 to 4 in which the continuous filaments comprise polyester filaments.

6. A composite lining material as claimed in any of claims 1 to 5 in which the lining layer comprises polypropylene or poly(vinylidene fluoride).

7. A composite lining material as claimed in any of claims 1 to 6 in which the reverse face of the lining layer is fused to the face of the non-woven fibrous web and to the continuous filaments stitched therethrough.

8. A composite lining material suitable for bonding to a reinforcement material substantially as hereinbefore described in any of the Examples.

9. A wall structure comprising a lining layer of a thermoplastic material having a lining face and a reverse face, a layer of reinforcement material, a non-woven fibrous web having one of its faces bonded to the reverse face of the lining layer and the other of its faces bonded to the layer of reinforcement material, and continuous filaments which are stitched through the web and which pass back and forth

between the lining layer and the reinforcement layer, being bonded to each of said layers at multiple, spaced locations.

10. A wall structure as claimed in claim 9 in which the layer of reinforcement material comprises a fibre-reinforced synthetic resin.

11. A wall structure as claimed in claim 9 or claim 10 comprising the wall of a pipe, vessel, or tank, for which the lining layer provides an internal lining.

12. A wall structure comprising a composite lining material as claimed in any of claims 1 to 8 and a layer of reinforcement material bonded to the exposed face of the fibrous web of said composite lining material.

13. A wall structure as claimed in any of claims 9 to 12 which gives a value of shear force as measured by the test described herein at a temperature of 20°C. of greater than 100 kg/cm².

14. A wall structure as claimed in any of claims 9 to 13 which gives a value of steady peel force as measured by the test described herein at a temperature of 20°C. of greater than 7.0 kg/cm.

15. A wall structure as claimed in any of claims 9 to 14 which gives a value of shear force as measured by the test described herein at a temperature of 50°C. of greater than 100 kg/cm².

16. A wall structure as claimed in any of claims 9 to 15 which gives a value of shear force as measured by the test described herein at a temperature of 100°C. of greater than 50 kg/cm².

17. A wall structure as claimed in any of claims 9 to 16 which gives values of steady peel force as measured by the test described herein at temperatures between 0°C. and 100°C. which fall at a rate of less than 0.01 kg/cm per 1°C rise in temperature.

18. A wall structure substantially as hereinbefore described in any of the Examples.

19. A wall structure substantially as hereinbefore described with reference to and as illustrated in Figures 3, 4 and 5 of the accompanying drawings.

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